Application of a multicriteria decision model for the classification of Paraíba's municipalities as to the occurrence of domestic and family violence against women

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Abstract The objective of the present work is to classify the municipalities of the state of Paraíba according to the propensity for the occurrence of Domestic and Family Violence Against Women. Data used come from the Municipal Basic Information Survey (MUNIC, in Portuguese), performed in 2019, by the Brazilian Institute of Geography and Statistics (IBGE, in Portuguese). Additionally, the records of cases of violence from the Women's Assistance Center (Ligue 180) were used to evaluate the classification. The ELECTRE Tri-B method was applied for the classification task, considering a set of socioeconomic criteria, to group municipalities into four classes: Low, Medium, High and Very High. The results suggest that more than 80% of the municipalities in Paraíba were classified as having a high propensity, which means that they have a lack of services and strategies to protect women, demanding, therefore, greater attention of the state for the implementation of assistance services.

Keywords: Violence against women, Multiple-criteria methods, ELECTRE Tri

1   Introduction

Violence against women contradicts several human rights and is configured as a social conflict very present in Brazilian and global society [Alves, 2023]. In Brazil, the discussion about domestic and family violence against women[1] has gained greater evidence with the approval of Law No. 11.340, dated August 7, 2006, widely known as Maria da Penha Law [CNJ and IPEA, 2019] and [Ribeiro, 2022].

In this sense, the Maria da Penha Law (LMP, in Portuguese) presents itself as the legal instrument that differentiated violence against women within marital relationships and in domestic and family environments, feminicide being the extreme case of this type of violence. The term feminicide was introduced into the Criminal Code in 2015, by Law No. 13,104 of March 9, 2015, bringing the specific criminal figure of homicide committed against women because of their gender condition.

According to the Ministry of Human Rights and Citizenship, domestic violence is the main cause of feminicide in Brazil and in the world[2]. The State of Paraíba, for example, ranked 7th with the highest feminicide crime rates among the Federal Units in 2019. In that same year, its proportion of the number of feminicide cases in relation

to the number of Lethal and Intentional Violent Crimes against women was 52%, that is, among all the registered cases of homicides with women victims in this state during the cited period, more than half were as a result of gender discrimination [Paraíba, 2020].

However, other forms of violence have also been presenting alarming numbers. In this context, data from the Brazilian Public Safety Forum for the year 2020, reveal that in 18 Federal Units there was an increase in cases of sexual violence against women, when compared with the previous year [de Segurança Pública, 2021]. At this point, the states of Paraíba (111.3%), Maranhão (46.3%), Alagoas (23.5%), Piauí (19.3%), and Sergipe (19%) stand out as having the most significant increases.

Given the above, we highlight the importance of research that addresses the universe of the problematic Domestic and Family Violence Against Women (DFVAW) and aims to assist in its confrontation, either through strategies for visualization of these data, as observed in [da Silva *et al.*, 2021], either through technological solutions that act in the defense of victims, as proposed in [de Freitas *et al.*, 2020].

Considering that the State of Paraíba stands out in relation to other Brazilian states in terms of the increase of sexual violence cases, as well as presenting high rates of feminicide, the approach proposed here aims to classify, by applying the ELECTRE Tri-B multicriteria method, the municipalities of the state as to the propensity to unreported DFVAW cases, based on factors frequently related, in the literature, to the

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[1]Given that the Maria da Penha Law already defines "domestic violence" as violence occurring within families or relationships, this term will also be employed in the text as an alternative.

[2]https://www.gov.br/mdh/pt-br/assuntos/denuncie-violencia-contra-a-mulher/violencia-contra-a-mulher. Acess on 23 March 2024.

occurrences. Among them, socioeconomic indexes from the Brazilian Institute of Geography and Statistics (IBGE, in Portuguese) and municipal information on the availability of victim assistance and protection services from the Municipal Basic Information Survey (MUNIC, in Portuguese).

Furthermore, we sought to investigate the relationship between the availability of these specialized services and the number of reports of violence of this nature[3]. This paper provides an analysis that can be used in the planning and direction of public policies for those municipalities that have a higher propensity to unreported DFVAW cases. The decision-makers and those involved in intervention planning can use this information to customize programs that specifically address identified areas of concern, allocate resources more effectively, and design preventive measures addressing root causes

The article is organized in such a way that Section 2 presents the theoretical framework. Section 3 presents the related works. The methodology used in the study is detailed in Section 4, while the results are analyzed and discussed in Section 5. Finally, Section 6 presents the final considerations.

2   Theoretical Framework

In this section, we will address the theoretical aspects of the main themes discussed in the work: domestic violence and its relationship with socioeconomic factors. Additionally, we will also discuss some important concepts for understanding the multicriteria technique used.

2.1   The Background of Domestic Violence

Violence against women represents a particular form of the global violence that is based on the patriarchal function that gives men the right to dominate and control women, and to do so, they can use violence [De Almeida *et al*., 1995]. Article 5 of the LMP defines DFVAW as *"any action or omission based on gender that causes death, injury, physical, sexual or psychological suffering, and moral or patrimonial damage"*, that occurs in the context of the domestic unit, with people with or without family ties; in the context of the family, with people who are or consider themselves related, connected by natural ties or by affinity; and in any relationship of affection, in which the aggressor lives or has lived with the victim, even if they do not live together.

In order to safeguard women's rights and prevent this type of violence from occurring, the LMP establishes that the States and Municipalities can promote, within the limits of their competence, the elaboration of public policies and the creation of specialized services, such as the implementation of women's assistance centers, shelters, specialized police stations, programs and campaigns to confront domestic violence, and education and rehabilitation centers for aggressors.

In this sense, it is possible to observe that the Federative Units have been guided by the elaboration and edition

of legal diplomas; by the elaboration and launching of public policies; and by the creation of agencies, foundations, autarchies, and apparatuses with the objective of combating domestic violence [SPM, 2011].

2.2   Domestic violence and the relationship with socioeconomic criteria

The analysis is based on studies showing that poor income conditions, access to health and education can be triggers for violent acts in the most diverse dimensions of violence [da Silva Alves, 2021]. The family composition and the place of residence can also be influential factors in cases of violence, according to a study by Martins and Teixeira [2020].

In the studies of Dias [2017], in turn, the author linked poverty and social exclusion as factors that impact domestic violence, listing unemployment, precarious work, low income, inadequate social support and protection services, as characteristics present among the actors involved in cases of domestic violence. Nevertheless, [Leite *et al*., 2017] attributes socioeconomic issues, more specifically the Human Development Index (HDI), to the higher probability of victimization.

It is noted that some of the factors mentioned above are encompassed by the HDI, whose value is based on health, education, and per capita income. Therefore, it was chosen to use it as a criterion in the methodology of this study. In addition, based on the cited studies, criteria such as Unemployment Rate, Literacy Rate, and Gross Domestic Product (GDP) - Per Capita were also considered, all of which were obtained from the Brazilian Institute of Geography and Statistics (IBGE). In addition to socioeconomic criteria, the approach also considered municipal information regarding the availability of services for victims' support and protection, derived from the Municipal Basic Information Survey (MUNIC).

2.3   ELECTRE Tri-B

According to Saaty [1990], decision making involves several criteria, which often conflict with each other, and using only one criterion may lead to insufficient results. Multiple Criteria Decision-Making (MCDM) is a methodology that encompasses computational techniques that assist in decision-making in scenarios involving the evaluation of multiple criteria and alternatives. The advantages of multicriteria methods include the ability to handle complexity in the decision-making process as the amount of data and information increases, in addition to the flexibility and parameter adaptation for different contexts. Another significant advantage is that several methods enable the incorporation of decision-makers' preferences, which can be expressed through the assignment of weights to the criteria.

There are various methods for multicriteria decision-making approaches for different decision problems. Each of them has its own characteristics and limitations that should be considered when making a choice. For the present study, the chosen method was ELECTRE Tri-B, which is

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[3]https://www.gov.br/mdh/pt-br/centrais-de-conteudo/ligue-180. Acess on 23 March 2024.

a variant of the ELECTRE family. Its selection is justified because it is an approach for ordered classification problems that compares alternatives to reference profiles formed by the boundaries of each pre-defined class.

Given that $G = g_1, g_2, ..., g_j$ is a set containing j criteria and each with a weight (level of importance) w_j, for $X = x_1, x_2, x_3, ...$ is a vector in R^j that represents the ratings of a generic alternative x on each criterion in G, and finally, whereas $B = b_1, b_2, b_3..., b_n$ is a set of $n + 1$ reference profiles where b_{h-1} and b_h are respectively the lower and upper bounds for the hth class.

For each class h and each criterion j, $g_j(b_h)$, represents the evaluation of the upper bound of hth class by the jth criterion. For each alternative x_i and each criterion j, $g_j(x_i)$, represents the evaluation of ith alternative for the jth criterion. Overclassification depends on the absolute value of the difference $g_j(x_i) - g_j(b_h)$, being greater than the predetermined thresholds of indifference (q_j), preference (p_j) and vector (v_j), where $v_j \geq p_j \geq q_j$. Then, the following steps are performed to obtain the overclassification relations:

a) Calculation of the degree of partial concordance $c_j(x_i, b_h)$ e $c_j(b_h, x_i)$

$$c_j(x_i, b_h) = \begin{cases} 0, & if \quad g_j(b_h) - g_j(x_i) \geq p_j \\ 1, & if \quad g_j(b_h) - g_j(x_i) < q_j \\ \frac{p_j - g_j(b_q) + g_j(x_i)}{p_j - q_j} & if \quad q_j \leq g_j(b_h) - g_j(x_i) < p_j \end{cases} \quad (1)$$

$$c_j(b_h, x_i) = \begin{cases} 0, & if \quad g_j(b_h) - g_j(x_i) \geq p_j \\ 1, & if \quad g_j(b_h) - g_j(x_i) < q_j \\ \frac{p_j - g_j(x_i) + g_j(b_q)}{p_j - q_j} & if \quad q_j \leq g_j(x_i) - g_j(b_h) < p_j \end{cases} \quad (2)$$

b) Calculation of the global concordance degree $C(x_i, b_h)$ e $C(b_h, x_i)$

$$C(x_i, b_h) = \frac{\sum_{j=1}^{n} w_j c_j(x_i, b_h)}{\sum_{j=1}^{n} w_j} \quad (3)$$

$$C(b_h, x_i) = \frac{\sum_{j=1}^{n} w_j c_j(b_h, x_i)}{\sum_{j=1}^{n} w_j} \quad (4)$$

c) Calculation of the degree of partial discordance $Dj(x_i, b_h)$ and $Dj(b_h, x_i)$

$$D_j(x_i, b_h) = \begin{cases} 0, & if \quad g_j(b_h) - g_j(x_i) < p_j \\ 1, & if \quad g_j(b_h) - g_j(x_i) \geq v_j \\ \frac{-p_j - g_j(x_i) + g_j}{v_j - p_j} & if \quad p_j \leq g_j(b_h) - g_j(x_i) < v_j \end{cases} \quad (5)$$

$$D_j(b_h, x_i) = \begin{cases} 0, & if \quad g_j(x_i) - g_j(b_h) < p_j \\ 1, & if \quad g_j(x_i) - g_j(b_h) \geq v_j \\ \frac{-p_j - g_j(b_q) + g_j}{v_j - p_j} & if \quad p_j \leq g_j(x_i) - g_j(b_h) < v_j \end{cases} \quad (6)$$

d) Calculation of the degree of credibility $\sigma(x_i, b_h)$ e $\sigma(b_h, x_i)$, that expresses confidence in the expression "x_i is no worse than b_h"

$$\sigma(x_i, b_h) = \begin{cases} C(x_i, b_h) \times \prod_{j=1}^{n} \frac{1 - D_j(x_i, b_h)}{1 - C(x_i, b_h)}, & if \quad D_j(x_i, b_h) > C(x_i, b_h) \\ C(x_i, b_h), & else \end{cases} \quad (7)$$

$$\sigma(b_h, x_i) = \begin{cases} C(b_h, x_i) \times \prod_{j=1}^{n} \frac{1 - D_j(b_h, x_i)}{1 - C(b_h, x_i)}, & if \quad D_j(b_h, x_i) > C(b_h, x_i) \\ C(b_h, x_i), & else \end{cases} \quad (8)$$

e) The overclassification decision still depends on a previously determined parameter, the lambda cut-off level (λ)

$$x_i Sb_h, \qquad Se \quad \sigma(x_i, b_h) \geq \lambda; \qquad 0.5 \leq \lambda \leq 1 \quad (9)$$

3 Related Work

For the selection of related works, we considered search criteria that applied different region classification approaches or spatial analysis, considering a scenario of violence, not limited to just gender-based violence [4].

It is possible to find in the literature studies that use computational techniques to help resolve issues in the realm of violence, such as the case of de Oliveira *et al.* [2019], who applied statistical measures to perform an Exploratory Data Analysis from 1,053 records of cases of domestic violence against women in the city of João Pessoa-PB, in the year 2017. The spatial distribution, represented by choropleth maps, enabled the observation of spatial patterns of the cases, as well as clusters throughout the capital.

In turn, [de Miranda Mota *et al.*, 2021] presented a model for identifying areas vulnerable to homicides in a neighborhood in the city of Recife, in Pernambuco, using the multicriteria DRSA (Dominance-based Rough Set Approach) method, considering factors such as income, education, and population density. In order to improve the quality of classification, the authors employed the K-means method to conduct a cluster analysis for selecting similar regions. Additionally, the work utilized a Geographic Information System (GIS) to create maps highlighting the vulnerable areas. The authors suggest that the classification obtained can guide public policies aimed at reducing violence in the highlighted regions.

In the work of Santos *et al.* [2021], a multicriteria approach is used to classify the municipalities of the State of Pernambuco into distinct categories regarding criminal characteristics based on nine criteria: vehicle theft, cargo robbery, robbery of financial institutions, robbery of buses, robbery of pedestrians, feminicide, homicide, armed robbery and bodily injury followed by death. The application of the model recommends security strategies for each defined category.

In a case study carried out in the Amazon, da Silva Costa *et al.* [2022] used the multicriteria Analytic Hierarchy Process (AHP), adopting the criteria of cases of violence, accessibility and female population, to propose a model to assist decision makers in choosing the most appropriate municipality for the implementation of the Brazilian Women's House, an important public equipment for assistance and protection of women in situations of domestic violence.

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[4]It is used as a more precise term that makes explicit reference to gender-related causes and will therefore also be used in the text as an alternative to "violence against women"

In the work of Ferrás Sexto *et al.* [2023], the aim is to analyze the spatial distribution of rates of violence against elderly women in a community in Spain and create a Location Map to guide public policies in regions with higher prevalence. The results were obtained through statistical analyses and spatial autocorrelation, such as Moran's I analysis. The authors also investigated the relationship between incidence and socioeconomic factors, such as low population density, age, and dependency. The results indicate that this type of violence is more prevalent in rural areas and areas with low population density.

The work by Fuerte-Celis and Sánchez-Castañeda [2021] conducts a cluster analysis to assess homicide rates in Mexico between the years 2000 and 2012. The analysis aims to observe spatial patterns by which municipalities can be classified based on variables related to higher incidence of cases. To achieve this, the authors employ geostatistical techniques such as the Moran's I Index and Getis-Ord G*i tests. To validate the clusters of cases and identify associated variables, the model utilizes the Random Forest learning technique. Finally, the proposed classification takes into account factors such as the presence of organized crime, patterns of population density, and socioeconomic inequality, which the authors identified as the main variables associated with the spatial patterns shown by homicide rates in the country.

The **Table 1** presents a comparison between the proposed model and the models proposed in related works in this section, indicating whether such works incorporate the described approaches.

To perform the comparison between the models, several crucial aspects in their respective approaches were taken into account: whether they employed any form of multi-criteria decision-making method; if they generated maps to visualize classified or selected areas; whether they considered socio-economic criteria commonly associated with the type of violence they are addressing; and finally, if the model incorporates some form of validation or evaluation of the applied technique, either through other methods, metrics, or evaluation by an expert.

It is important to emphasize that during the research of existing works, few articles were found that applied MCDM in the context of violence mapping. Therefore, the approach proposed here stands out for its contribution to the literature by integrating the use of ELECTRE Tri-B to classify regions in the context of DFVAW, considering socio-economic criteria associated with this type of violence, and the public facilities for victim protection, along with the geographical mapping of the classified areas. Furthermore, the proposed evaluation is a means of ensuring that the results accurately reflect the reality of each region, by comparing the number of reported cases with the SPI values and socioeconomic indicators presented by each municipality.

4 Methodology

The study is classified as exploratory because of its nature of investigation, since it proposes to make a broad and comprehensive research on the topic of Domestic Violence,
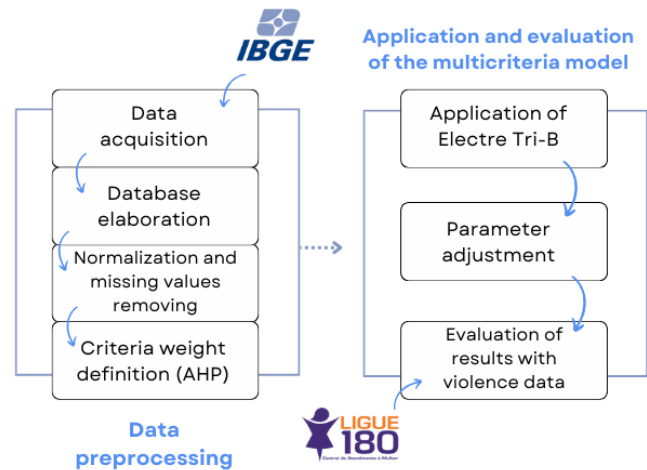

Figure 1. General Research Methodology

considering indicators that are commonly related to the problem. The methodology for the development of the work is based on a series of steps to deliver the results and are presented in **Figure 1**.

4.1 Data preprocessing

According to IBGE data for 2021, the State of Paraíba, the selected study site, has 223 municipalities divided into 12 metropolitan regions, with an estimated population of 4,059,905 inhabitants, 2,101,744 women and 1,958,161 men.

Once the database has been created, possible inconsistencies in values were checked, such as incorrect or missing data, in order to perform data processing. After that, the descriptive statistics of the data were observed (See **Table 2**) to understand their distribution and make the necessary transformations. In the case of criterion C5 (Unemployment Rate), it was necessary to invert its values, as its original meaning (the lower the value, the better) does not align with the order of the other criteria. Furthermore, to facilitate the application of ELECTRE Tri-B, the criterion values were transformed to a scale between -1 and 1. The order relationships of the original values were maintained.

The data of the municipalities, such as the socioeconomic indicators, were acquired through the data services API of IBGE[5]: HDI, Literacy and Unemployment rate referring to the 2010 Census and GDP Per Capita referring to the year 2019. The Python libraries Request[6] and Pandas[7] were used to manipulate the API and obtain the data and for database composition and preprocessing, respectively. Thus, the database was composed and organized in such a way that the rows correspond to the 223 municipalities in Paraiba, and the columns represent the criteria values.

The SPI criterion was formed by integrating indicators obtained by the 2019 Municipal Basic Information Survey[8] (MUNIC, in Portuguese), referring to the availability of policies, services, and actions specialized in the care and protection of victims and survivors of domestic violence

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[5]https://servicodados.ibge.gov.br/api/docs. Acess on 23 March 2024.
[6]https://pypi.org/project/requests/. Acess on 23 March 2024.
[7]https://pandas.pydata.org/docs/. Acess on 23 March 2024.
[8]https://cidades.ibge.gov.br/brasil/df/brasilia/pesquisa/1/74454?ano=2021. Acess on 23 March 2024.

Table 1. Comparison of related work

Article	Multicriteria methods	Mapping of risk areas	Socioeconomic criteria	Validation or evaluation of the classification
[de Oliveira *et al.*, 2019]		X		
[de Miranda Mota *et al.*, 2021]	X	X	X	X
[Santos *et al.*, 2021]	X			
[da Silva Costa *et al.*, 2022]	X			
[Ferrás Sexto *et al.*, 2023]		X	X	
[Fuerte-Celis and Sánchez-Castañeda, 2021]		X	X	X
Proposed model	X	X	X	X

X - Incorporate the approach

Table 2. Descriptive statistics of Paraíba database

Criterion	Minimum value	Maximum value	Mean
C1	0.0	4.5	0.8
C2	0.513	0.763	0.587
C3	6726.47	96359.3	10953.0
C4	60.9	92.4	73.03
C5	0.8	21.23	7.00

in each municipality. In summary, the SPI is a weighted sum, in which each element (indicators) is multiplied by an associated weight and then the products are added together to obtain the final result. The attribution of the weights was based on the perception of the authors, such that, to the indicators with a greater and immediate impact on the problem, a weight of 1.5 was defined; 1.0 for medium impact and 0.5 for lesser and not immediate impact. The MUNIC indicators used and their respective weights are described in the **Table 3**

Table 3. Indicators of care services

Code	Description	Weight
90201	It has specialized police stations	1,5
90358	It has specific legislation for gender-based violence	1,5
90640	It has human rights protection programs for victims and survivors	1,0
90626	Conduct conferences on the topic of women's rights or policies	0,5
90397	Constitution of reference and service centers for human rights	0,5

To compose the database, the following criteria were selected:

- Support and Protection Index (C1): Aggregation of variables from the Municipal Basic Information Survey regarding the availability of services for victims of Violence Against Woman.
- Human Development Index (C2): A statistical measure that assesses the human development of countries based on three dimensions: health, education, and per capita income.
- GDP Per Capita (C3): An economic measure that represents the average economic output per inhabitant of a given country or region.
- Literacy rate (C4): The rate is the division of the number

of people aged 10 or older who are literate by the corresponding age group population, multiplied by 100.
- Unemployment rate (C5): It is the percentage of people aged 16 or older in the workforce who are unemployed in the year of the survey.

In order to define the weights of the criteria, the Analytic Hierarchy Process (AHP) [Saaty, 1990], a MCDM method that constructs a hierarchical analysis of the criteria, was used. Once the criteria are defined, it is necessary to construct the judgment matrix, an initial step of the method used to assess the importance of the criteria. This process is carried out through pairwise comparisons, which are measured using values based on the SAATY scale, as shown in **Table 4**.

Table 4. SAATY scale

Intensity of importance	Rating scale	Reciprocal
Equal importance	1	1
Moderate importance	3	1/3
Strong importance	5	1/5
Very strong importance	7	1/7
Extreme importance	9	1/9
Intermediate values	2,4,6,8	1/2, 1/4, 1/6, 1/8

The pairwise comparisons (**Table 5**) was based on [Martins and Teixeira, 2020], which considers the presence of public facilities in municipalities as essential, as they contribute to increasing the sense of security for victims and, consequently, to the reporting of complaints. Therefore, a higher importance was assigned to SPI. Due to its failure to consider income inequality within the population, less importance was attributed to GDP Per Capital. Equal importance was assigned to the other criteria.

Table 5. Criteria judgment matrix

	C1	C2	C3	C4	C5
C1	1	5	3	3	3
C2	1/5	1	1/3	1/3	1/3
C3	1/3	3	1	1	1
C4	1/3	3	1	1	1
C5	1/3	3	1	1	1

To assess the consistency of the judgment matrix, the Consistency Ratio (CR) was calculated. SAATY defines that an acceptable CR value should be less than or equal to 0.10.

For CR values > 0.10, it is recommended to review the matrix. The calculated CR was 0.9.

The judgment matrix and the other calculations required to achieve the AHP objective were applied using the Python library pyDecision, which simplifies the implementation of various multicriteria methods. As a result of the application, weight values were determined for each criterion. The assignment of weights is depicted in **Figure 2**.
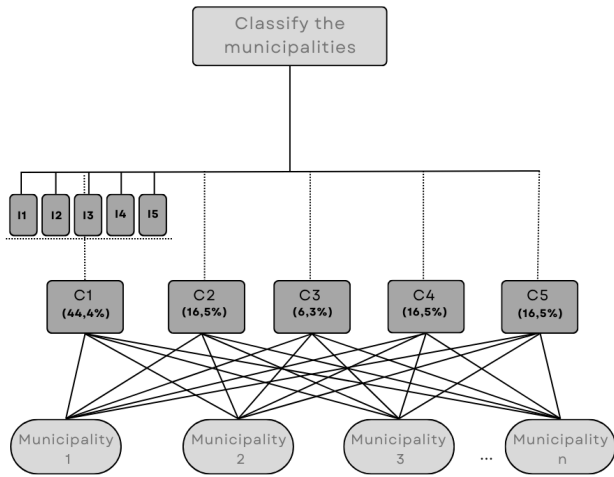

Figure 2. Assigning criteria weights

4.2 Application and evaluation of the multicriteria model

The ELECTRE Tri-B method was applied using the pyDecision library. For the method in question, there are some important parameters to be defined: Q = Indifference; P = Preference; V = Veto; W = Criterion Weights, and B = Thresholds. The thresholds define a minimum required level of performance in each criterion for an alternative to be considered viable for a particular class. For this work, the thresholds between the classes were defined using a Python function to capture the quartile values of each criterion. The definition of three thresholds characterizes the distribution of alternatives into four classes (See **Figure 3**).

Figure 3. Thresholds and classes.

The parameters of indifference (Q) and preference (P) indicate, in this order, the minimum and maximum acceptable values during the overranking process. For their definitions, one should adhere to condition $v_j \geq p_j \geq q_j$

(See **Table 6**). The weights (W) of the criteria were defined beforehand using AHP.

Table 6. ELECTRE Tri-B parameters inferences

Parameters	C1	C2	C3	C4	C5
Q	0.2	0.2	0.2	0.2	0.2
P	0.4	0.4	0.4	0.4	0.4
V	1.0	1.0	1.0	1.0	1.0
W	44.4	16.5	6.3	16.5	16.5

For a better visualization of the classification and possible clusters of municipalities, the methodology proposed the use of the Geopandas library[9] and the IBGE's geographic mesh API to create maps of Paraíba with the classes assigned to their municipalities.

For the evaluation of the classification, we chose to use data from reports of domestic violence from the Central de Atendimento à Mulher, in the year of 2022, which are reports of data recorded by "Ligue 180", a helpline in Brazil focused on combating gender-based violence. It allows individuals to report incidents, seek guidance, and access information about women's rights and support services. The use of this data for the evaluation is justified by the research of Martins and Teixeira [2020], which points out that the quantity of reports is directly related to the availability of care and protection services, since this support provides women with greater security to report their aggressor.

5 Results

This section discusses the main results obtained with the classification of the 223 municipalities of Paraíba using the ELECTRE Tri-B. From the application of the method, the municipalities were distributed into four classes, regarding the propensity[10] of DFVAW cases: i) Low (25); ii) Medium (11); iii) High (104); and iv) Very High (83). The relation of municipalities per class can be seen in the GitHub repository of the project.

Of the total of 223 municipalities in Paraíba, 187 were classified with "Very High" and "High" propensity to unreported cases of DFVAW, indicating that in 83.85% of the municipalities in Paraíba there is a shortage of resources for combating gender-based violence. In the same sense, only 11.21% of the municipalities in the state were categorized with Low propensity for the occurrence of this type of violence.

Among the municipalities classified as "Very High", Gado Bravo and Casserengue stand out. Both presented the lowest HDI values in the state: 0.513 and 0.514, respectively. In turn, the GDP Per Capita of the municipalities of Gado Bravo and Casserengue was R$ 8,019.62 and R$ 8,190.27 and the Literacy Rate was 70.2 and 63.4, respectively, which are lower values than the average of Paraíba in the year of study. According to the analysis of the indicators selected for the SPI, the absence of policies, services, or actions aimed at

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[9]https://geopandas.org/en/stable/. Acess on 23 March 2024.
[10]In this context, the term "propensity" refers to the tendency or likelihood of unreported cases of domestic violence.

the care and protection of victims and survivors in these municipalities was identified.

On the other hand, among the municipalities categorized with "Low" propensity to unreported cases of DFVAW, the following stand out: Guarabira, Patos, Bayeux, Cabedelo and João Pessoa. Besides the socioeconomic indices above the average of Paraíba's values, these municipalities presented the highest values in the SPI criterion: 4.5, 4.5, 4.0 and 3.0, respectively. It is possible to observe that they make available a wide network of protection to women, composed, in great part, by specialized police stations, specific legislation, and socio-educational actions.

In the analysis of the class map obtained by applying the model, seen in **Figure4** (A), where the darker areas represent regions with higher propensity to unreported DFVAW cases and the lighter areas lower propensity, it is observed that the municipalities in the "Low" class are spatially dispersed.

These results reflect particularities of the region studied, since most of these municipalities are located in Metropolitan Regions of the State[11], as can be seen in **Figure 4** (B).

The development of an interactive map of the classification is essential for assisting in the visualization of results, making it easier to identify the most vulnerable regions and, consequently, facilitating the actions of public agencies in combating DFVAW. Based on this premise, **Figure 5** displays the interactive map developed from the model's results. The interactive map is available in the GitHub repository of the project.

Therefore, the model was evaluated by comparing the classification and the number of complaints obtained from "Ligue 180", in order to identify if there was a relationship between the highest values of the assistance and protection network and the highest number of cases per municipality. **Table 7** and **Table 8** show a sample of five municipalities in the Low and Very High classes, respectively, ordered by the highest and lowest values of SPI. To facilitate the comparison between municipalities, the case rates per 100,000 inhabitants was included, utilizing the number of cases and the population from the 2022 Demographic Census.

For the sample of the Low class, the data show cities with good socioeconomic indicators and SPI, along with high numbers of reports, which implies that women living in these metropolitan areas feel safer to report their aggressors. In the sample of the Very High class, the opposite is observed: lower socioeconomic indicators, low SPI, and few or no registered cases, which may indicate underreporting, a phenomenon in which many cases of violence against women are not reported to authorities or recorded in official statistics.

Additionally, the **Table 9** enriches the discussion by enabling the correlation between reported cases and the presence of specialized services (SPI or criterion C1), as well as highlighting potential underreporting in different municipalities. To achieve this, localities with socioeconomic indicators and populations similar or close to those presented in **Table 8**, were meticulously selected, with notable discrepancies in the rates of cases per 100,000

inhabitants. When analyzing Mulungu and Serraria, for instance, despite their socioeconomic similarities, there is a significant disparity in their case rates (2.2 and 73.6, respectively). Even considering that Mulungu has twice the population of Serraria, only two cases were reported in 2022 by Ligue 180, highlighting the impact of the presence of protection and assistance services on the quantity of reports in the municipality of Serraria.

Caiçara, with socioeconomic indicators and a population similar to those of Cuité de Mamanguape and Cuitegi, recorded a case rate twice as high (51.4), despite not having, until the year MUNIC was published, any of the specialized services covered by the survey. This not only suggests a high probability of unreported cases in the municipalities mentioned above, but also highlights that the number of cases in towns like Caiçara could be further exploited with the presence of specialized services, which justifies its label for "Very High". As for the classification made by the ELECTRE Tri-B, it is understood that the three municipalities, despite the difference in the number of complaints, as well as having unfavorable socioeconomic indices that contribute, according to the literature, to the cycle of domestic violence, also lack a protection network to deal effectively with preventing and combating DFVAW.

The municipalities of Barauna and Pedra Lavrada, classified as "Low", although they don't have the highest socioeconomic indices in the state of Paraíba, presented a good value in the SPI criterion (3.0); Pedro Regis, classified as "High" propensity, had lower SPI, HDI, GDP and Literacy Rate. Despite having a higher case rate than Pedra Lavrada's, it is important to consider that the evaluation with Ligue 180 cases, although contributing significant correlations, should not be considered the sole determinant in the classification evaluation.

Other municipalities analyzed, although not included in the sample tables, also deserve attention. Campina Grande, located in the second Metropolitan Region created in Paraíba, presented an SPI of 3.0 and was classified as "Low" in propensity, with excellent socioeconomic indices, such as a GDP of R$ 23,204.57, HDI of 0.720, and a Literacy Rate of 89.1. When examining reported cases of domestic violence in 2022, the municipality presented a rate of 48.5 cases per 100,000 inhabitants, a value close to that observed in the state capital, João Pessoa.

Barra de Santa Rosa, classified as "Medium" propensity, despite having an SPI of 2.5, showed one of the lowest Literacy Rates (66.2), along with a low HDI value (0.562). Its rate of cases per inhabitant was 29.4, a higher value compared to Cabedelo, classified as "Low" (**Table 7**). However, Cabedelo stands out in the classification by presenting good socioeconomic indices and an SPI of 3.0.

6   Final considerations

Domestic violence is a social problem that affects women worldwide. In Brazil, DFVAW rates present alarming data and a growing trend. Given this scenario, the present study aimed to use ELECTRE Tri-B to support multicriteria decision-making in classifying the municipalities of Paraíba

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[11] https://fnembrasil.org/pb. Acess on 23 March 2024.
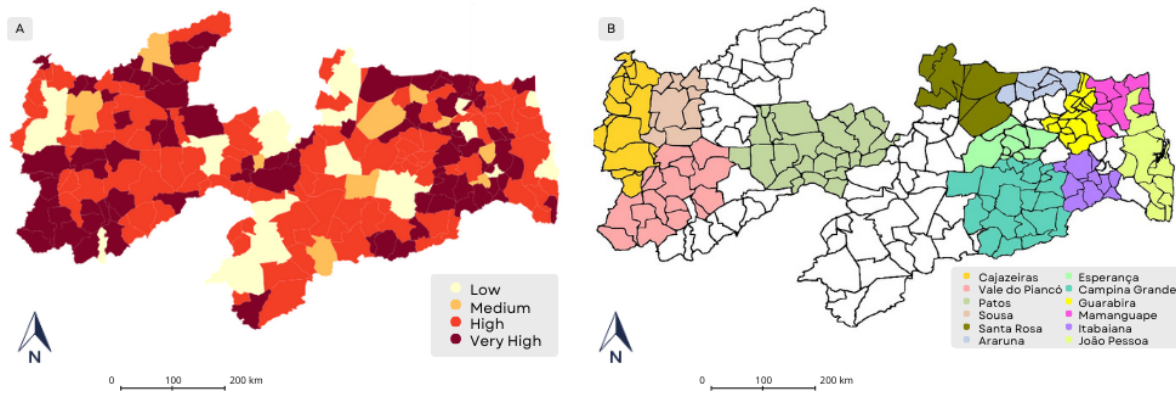
Figure 4. (A) Map of the classes obtained with Electre TRI-B. (B) Map of the Metropolitan Regions of the State of Paraíba.

Table 7. Sample with five municipalities in the lower class

Municipality	C1	C2	C3	C4	C5	Class	Cases	Case Rates
Guarabira	4.5	0.673	18.469,77	81.4	8.57	Low	176	30.6
Patos	4.5	0.701	17.788,29	82.9	8.4	Low	315	30.5
Bayeux	4.0	0.649	14.328,5	85.7	11.71	Low	588	71
Cabedelo	3.0	0.748	43.137,95	90	11.46	Low	185	27.8
João Pessoa	3.0	0.763	25.767,15	92.4	9.74	Low	3.673	44

Table 8. Sample with five municipalities in the very high class

Municipality	C1	C2	C3	C4	C5	Class	Cases	Case Rates
Cuité de Mamanguape	0.0	0.524	9.521,51	62.1	14.57	Very High	15	23.9
Santa Inês	0.0	0.572	8.689,03	70.8	13.82	Very High	0	0
Vieirópolis	0.0	0.571	7.819,5	65.1	9.19	Very High	6	12.3
Cuitegi	0.0	0.570	9.371,82	69.2	14.19	Very High	15	22.2
Mulungu	0.0	0.565	8.205,1	67.3	12.66	Very High	2	2.2

Table 9. Sample of selected municipalities to evaluate the impact of SPI

Municipality	C1	C2	C3	C4	C5	Class	Cases	Case Rates
Serraria	3.0	0.547	9.449,34	63.0	4.59	Medium	36	73.6
Barauna	3.0	0.558	9.078,01	74.4	6.83	Low	49	102.8
Pedra Lavrada	3.0	0.574	9.167,97	74.6	5.69	Low	30	43.7
Caiçara	0.0	0.592	8.229,55	68.7	7.9	Very High	34	51.4
Pedro Regis	1.5	0.542	8.193,69	61.3	5.27	High	26	45
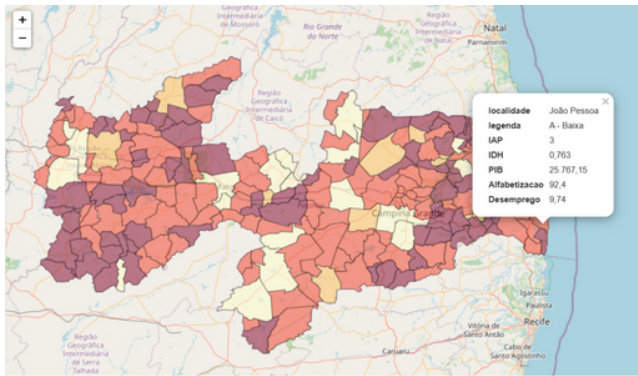
Figure 5. Interactive map of the classification

regarding the occurrence of this type of violence. The classification is grounded in socioeconomic factors and the presence or absence of support services for victims of domestic violence.

In addition, the methodology proposed a mapping to identify regions with a higher propensity, taking into account the socioeconomic factors mentioned in the literature, for the occurrence of DFVAW, especially in areas where specific public measures to mitigate this problem have not yet been implemented.

In what concerns the results obtained, the application of the ELECTRE Tri-B method met the research expectations by providing a satisfactory classification of municipalities, expressing decision-maker preferences in a multicriteria context. Furthermore, by comparing the classification of municipalities with the number of records of violence, it is possible to imply the existence of the relationship between good socioeconomic indexes and the presence of a broad network to fight domestic violence to encourage women in situations of violence to report their aggressors, as evidenced in the studies cited above. On the other hand, municipalities classified with higher propensity are those with lower socioeconomic indices, and it is also possible to observe the absence or fragile structure to combat DFVAW.

It is essential to emphasize that the data used in this research have public precedence, providing them with accessibility and transparency. Additionally, there is trust in the rigor of the methodologies employed by the research organizations, reinforcing reliability in the consistency of data and of the presented results. However, it is equally important to address potential limitations regarding the use of this data, especially concerning the non-inclusion of all indicators of victim support and protection services against violence in a municipality, presented by MUNIC.

Furthermore, the use of 2010 Census data was necessary due to the unavailability of more recent data at the time of the study. This temporal disparity represents a potential impact on the analysis, considering that the data are municipal socioeconomic indicators and may not reflect significant changes occurring after 2010.

In addition, it is important to note that the use of data on complaints from Ligue 180, although it has made considerable contributions, also has limitations. The records used refer exclusively to the year 2022, which may not fully reflect the dynamics of domestic violence over time in the municipalities analyzed. Furthermore, Ligue 180 is

not the only reporting portal available in a city, suggesting that the number of cases registered may not fully reflect all occurrences. This consideration highlights the importance of using a more comprehensive approach when evaluating the model.

For future works we suggest the use of others methods for validation of the model, thus allowing a comparison with the results obtained in this study. Additionally, we recommend further investigations into potential regions affected by underreporting when conducting the analysis of domestic violence cases. Moreover, it is expected that the criteria values can be updated once the data from the 2022 Demographic Census are fully published.

Finally, considering the complexity of the factors involved in the cycle of Domestic and Family Violence Against Women, it is important to mention the relevance of the proposed approach as a means to facilitate decision-making involving the prioritization of regions for the implementation of public policies.

Declarations

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Authors' Contributions

The authors Alana Medeiros and João Júnior made significant contributions to the conception of this study, developing the methodology and multicriteria models. Marisa Andrade, Saulo Costa, and Fernando Costa were involved in the Writing – original draft, contributing to the writing, revision, and translation of this article. Marcos Seruffo and Nelson Neto supervised and managed the project, as well as conducted the review and editing of the article. Alana Medeiros is the main contributor and author of this article.

Competing interests

We, the authors of this work, declare that there are no conflicts of interest in this study, whether financial, personal, institutional, academic, or of any other nature.

Availability of data and materials

The source code for this work and the datasets are available on the authors' github repository in: https://github.com/AlanaMiranda/Classification-PB.

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